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Experiences with tasks supported by a cognitive e-learning system in preschool: Modelling and training on working memory and attentional control

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ABSTRACT

Improvements in executive functions appear to have a strong impact on preschool learning activities and academic performance. This paper presents some experiences in training working memory and attentional control supported by an educational software system called APRENDO. The aims were to assess the suitability of the APRENDO system as a computer-based learning system in terms of improvements in these two executive functions, and to establish whether the tasks help children – especially children with the poorest performance – in a school task requiring the use of both processes. The participants were 52 four-year-old children, divided into a control group and an experimental group. The experimental group trained with two types of APRENDO visuospatial exercises: "Find the different objects" and "Find the intruder". Before and after the training phase, all the children performed a school task with similar psychological demands selected from their ordinary school materials. The results of both APRENDO exercises showed positive correlations between the same variables over the training sessions, demonstrating the suitability of the exercises. On the other hand, in the experimental group, there were significant differences between some of the variables analyzed, e.g., the time needed to complete the exercises ("Answering time") or the number of clicks on the correct images ("Answer accuracy") in both exercises during the sessions. The results indicate that the children who obtained lower scores in the pre-test phase were those who benefitted the most from training. The analysis of the errors made by the children in both tasks suggests that these errors are due to the incorrect application of the same cognitive abilities. The implications for educational practice are discussed.

1. Introduction

The educational and psychological literature shows that the early years of schooling, from 3 to 5 years, are crucial to the development of educational and developmental processes. At this stage, academic demands require the use of skills (perceptual, linguistic, attentional, memory, etc) that are more complex than the ones usually needed in the family setting (Boujon and Quaireau, 1999; Diamond et al., 2007; Gerardi, 1997; Rueda et al., 2005; Welsh et al., 2010). Attentional control and working memory are two of the key functions needed to perform many school tasks (Miyake et al., 2000).There are studies demonstrating that executive functions can be improved in pre-schoolers in regular classrooms and the benefits are transferred to other activities (Diamond et al., 2007; Diamond and Lee, 2011; Cogmed Working Memory, 2014). Teachers can train the cognitive functions using the tools and techniques common to primary education as well as computer programs specifically designed for this purpose (Diamond and Lee, 2011; Grunewaldt et al., 2013; Rueda et al., 2005) There are some interesting systems based on psychological principles (Aleven and Koedinger, 2002; Arroyo et al., 2006; Roll et al., 2011), although few systems have been specifically created to aid in the cognitive development of young children at school (Sung et al., 2008).

We have implemented PATIO, a generic computer-based learning framework (described in more detail in Section 1.2). It has been designed specifically for early childhood education. It provides a set of generic services for defining, delivering, assessing and monitoring learning activities. It includes learning tools specialized in different educative areas for small children (such us writing, reading and training cognitive skills) that use those generic services. One of these tools is APRENDO (Trella et al., 2008)

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that focuses on basic cognitive skills such as attention or memory development. This paper describes a research done with APRENDO tool.

The main aims of this study were (1) to test the suitability of the APRENDO system as a learning system for training working memory and attentional control in preschool children (Markopoulos et al., 2008), and (2) to conduct a pilot study to explore whether APRENDO can improve attentional control and working memory in younger children. This paper describes an experiment conducted with children between 4 and 5 years old in preschool who used the APRENDO system activities between typical school tasks. This study used a repeated measures pre-test/training/post-test design with an experimental group (EG) and a control group (CG). In the pre-test and post-test conditions, both groups performed a pen and paper task or compulsory and curricular school tasks with psychological requirements similar to those of the APRENDO exercises. The experimental group trained with two types of APRENDO visuospatial exercises: "Find the different objects" and "Find the intruder".

The rest of the paper is organized as follows. Section 1.1 reviews previous studies performed in the pre-schoolers executive functions training domain. Section 1.2 describes the basics of PATIO educative framework. At the end of this introduction, the concrete objectives of the present study are presented. Afterward, the method (participants, procedure and measures) and the results (statistical studies) of the experiences are explained in detail in Sections 2 and 3 respectively. Finally, we conclude by analyzing and discussing the results in Section 4, and we consider the recommendations for future studies, and the implication for educational practice in Section 5.

1.1. Computer-based learning systems to promote attentional control and working memory in preschool children

School learning is a cumulative process in which knowledge is built up year by year with an increase in the number and complexity of cognitive processes and strategies needed for school tasks. Thus, it is important that these processes and strategies are active and responsive to the needs of learning from infancy onwards. Attentional control and working memory are the two key executive functions needed to perform many school tasks that require concentration, the inhibition of distractions, remembering the characteristics of the stimuli or known information, and giving accurate and rapid answers (Miyake et al., 2000).

There is a considerable body of work on the complexity of these two capacities (Baddeley, 2006; Bialystok and Martin, 2003; Callejas et al., 2004; Fan and Posner, 2004; Gathercole et al., 2006; Gathercole et al., 2004; Miyake et al., 2000; Posner, 2004; Posner and Petersen, 1990; Rueda et al., 2005) and their importance for information processing and school learning (Bull and Scerif, 2001; Bull et al., 2008; Deustch and Deustch, 1963; Dunham, 1995; Foster and Watkins, 2010; Gathercole et al., 2006; Jankowski et al., 2001; Jones et al., 2003; Loe et al., 2008; Ruff and Rothbart, 1996; Thorell et al., 2009; Wassenberg et al., 2005; Welsh et al., 2010; Wickens, 1984). Developmental research shows that executive control begins to develop from 3 to 6 years onward and that, as the children grow, attention improves in three dimensions: control, flexibility, and planning strategies, although studies on normally developing preschool children remain scarce (Rueda et al., 2004). Furthermore, these studies rarely take into account the initial signs in preschool that predict major attentional difficulties, such as attention deficit hyperactivity disorder. Thus, attentional control has been shown to be an essential element in academic learning outcomes, although it also influences emotional regulation which, in turn, has a direct impact on academic outcomes in primary school (Buhs et al., 2006; Chang and Burns, 2005; Friedman-Weieneth et al., 2007; Normandeau and Guay, 1998; Posner and Rothbart, 2007; Rose et al., 1999; Rothbart and Posner, 2006; Vasey et al., 1996). Working memory is a key function needed for cognitive tasks, but has been little studied in normally developing younger children. Working memory consists in simultaneously maintaining and processing information over a short period of time. It has a close relationship with attentional control because it appears to be related to the ability to resist distractions and irrelevant stimuli and the ability to concentrate on information relevant to completing tasks (Gathercole et al., 2012).

On the other hand, school is an essential context for child development at early ages, not only because initial difficulties in the learning process can be early detected, but because interventions can be conducted to improve the psychological skills and strategies involved in these problems (Chang and Burns, 2005; Grunewaldt et al., 2013; Ladd et al., 2006; Loe et al., 2008; McClelland et al., 2006). Executive functions can be improved in pre-schoolers in regular classrooms and the benefits are transferred to other activities (Diamond et al., 2007; Diamond and Lee, 2011). Teachers can train the cognitive functions needed for school tasks using the tools and techniques common to primary education: classroom curricula, pen and paper exercises, motor games, aerobic exercise, music, poetry, drama, and cognitive or linguistic enrichment tasks, etc., as well as computer programs specifically designed for this purpose (Diamond and Lee, 2011; Grunewaldt et al., 2013; Rueda et al., 2005). The theoretical model underlying many of these interventions often assume a Vygostkian approach of mediated learning and cognitive modification (Calero, 1995; Bodrova and Leong, 2007; Feuerstein et al., 1979; Holdich and Chung, 2003; Vigotsky, 1978). Training can be treated as an active phase with monitoring and guidance, with the aim of coaching the students in those basic strategies that lead to better performance in a specific domain. Such training is carried out between two sessions addressing the same task, formal or otherwise, that functions as a test and helps to detect academic progress. Thus, although there is an increase in the complexity of academic and behavioral tasks during childhood, skills improve if the learning conditions follow the orientation of this model (Holdich and Chung, 2003; Kolhberg, 1986; Kitchener, 1986; Vigotsky, 1978), that is, when the learning tasks: (1) are motivating and contextualized; (2) include prior knowledge or hints and clues that the child knows; and (3) are carried out in the presence of more experienced children.

Computer-based learning systems can form part of the settings which promote these conditions. After our experience with small children in the classroom, we have observed that the inclusion of these tools in the classroom has important advantages: (1) interactive tasks can be performed that cannot be done with traditional materials; (2) computers motivate children and the feedback received after each action is interpreted as part of the task and not as a penalty; (3) the content and materials can be reused; and (4) the tasks are modeled as a problem-solving workflow composed of a set of steps. Thus, the learning process can be monitored and situations can be detected in which help and intervention can be directly provided by the teacher or automatically, by the tool itself; and (5) both the learning process and results can be studied and analyzed.

However, different researchers have questioned the suitability of the use of computers by children aged from 3 to 6 years. As stated by Plowman and Stephen (2003), the question is not "At what age should children use computers?" but "What are appropriate and meaningful uses of technology with children?". If the technology is used properly it can be a useful tool in the development and learning of young children (Abbott et al., 2001; Bolstad, 2004). Some studies have proposed guidelines for the development of software for children (D'Mello et al., 2012; Gelderblom, 2004; Isomursu et al., 2011; Mooij, 2007; Park and Hannafin, 1993), although these guidelines are generic and therefore difficult to apply when the system must be customized to a specific domain and psychological theory of learning.

Computer training has been shown to improve working memory and reasoning in children aged 4–5 years, but experiences